Internal Tide Generation in the Indonesian Seas

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LONG-TERM GOALS

Characterize the internal tides in the Indonesian Seas and determine how they may vary seasonally and interannually as the thermocline structure changes.

OBJECTIVES

Our primary objective is to provide reliable estimates for the barotropic and baroclinic tides in the Indonesian Seas. We intend to determine: 1) specifically where in the Indonesian Seas baroclinic tides are generated and propagated, and, if time allows, 2) the effect of the seasonally and ENSO driven North Pacific versus South Pacific thermohaline structures on internal tide generation.

APPROACH

The barotropic and baroclinic tides in the Indonesian Seas will be estimated by using the Regional Ocean Modeling System and by analyzing the available observational data. This project will proceed in two phases. In one phase, two types of existing observational data will be analyzed for tidal signals: the available velocity, temperature, and pressure data from the ARLINDO moorings and, as best possible, eighteen years of XBT data. The analysis of the observational data will be key in that they may provide critical tidal information in the mid-thermocline away from the coastal regions. As the physical presence of tidally induced turbulence and mixing modifies acoustical signal propagation and because the internal tides are responsible for significant heaving of the thermocline in the Indonesian Seas, it is paramount to extract as much tidal information as possible from the available observational data sets. In the other phase, tidally forced simulations using ROMS will be performed on two domains in the Indonesian Seas, having fine scale (~1 km) and medium scale (4 km) resolutions (Figure 2). The smaller domain will focus on the region of available mooring observations and the larger domain will provide a characterization of the baroclinic tides for a broader region of the Indonesian Seas. Both the observational and modeling results will be used to describe the barotropic and baroclinic tidal fields, and to determine where baroclinic tides are generated and propagated.

WORK COMPLETED

Work on this project commenced 2.5 months ago on July 1, 2003. Since then, both the 1 km and 4 km grids have been set up using bathymetry from Smith and Sandwell (1997) and hydrography from

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profiles in the region obtained by averaging hydrography data from recent international cruises and the NODC archives. Input files for the boundary conditions were taken from Egbert et al. (1994) global tidal model for eight constituents. The simulations are in progress. Although, the simulations are taking more time than expected, 2-3 weeks, and power outages have caused some delays, work is proceeding as scheduled. In addition, estimates of the magnitudes of the tides from the ARLINDO mooring data are in progress, and the XBT observational data has been acquired from CSIRO and preliminary analysis started.

RESULTS

A Root-Mean-Square (RMS) analysis of the XBT data in the Indonesian Seas is being carried out in order to most simply characterize the possible higher frequency variability in the Indonesian thermocline far away from the coastal regions. While, the analysis of the mooring data will give excellent results, only a few locations have ever been monitored in the Indonesian Seas. However, the XBT data has the potential to identify larger geographic regions possibly influenced by tidal heaving.

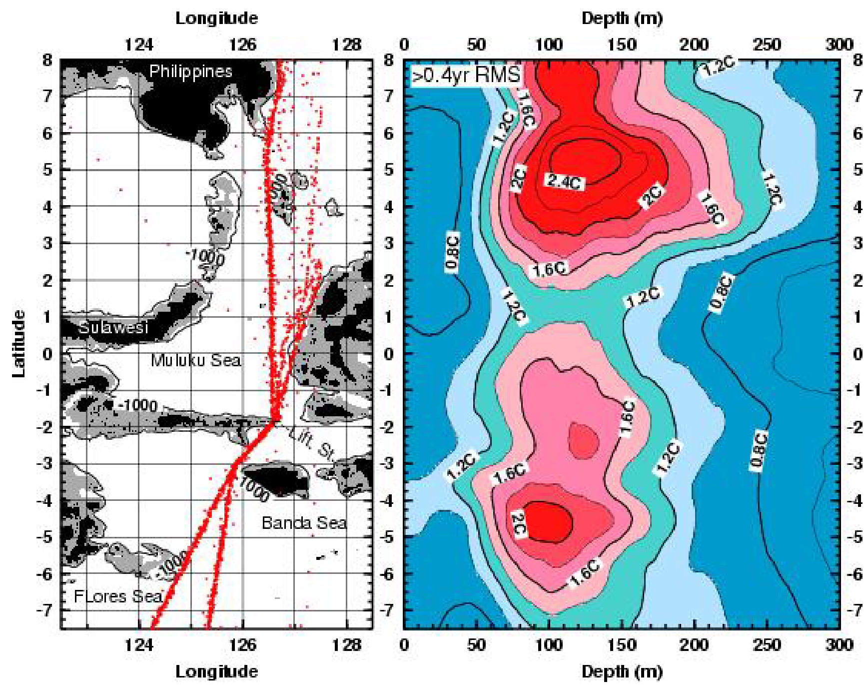

Figure 1. In the left panel the location of the XBT drops are shown, and in the right panel the Root-Mean-Square (RMS) of the smoothed XBT temperature data as a function of latitude and ocean depth is shown. The temperature data was first smoothed by a 0.4 year running Gaussian mean. Consequently, the RMS values reflect the variability of the semi-annual, annual, and inter-annual temperature variations. By far, the largest RMS values are observed centered at latitude 5 S (and 120 m depth), in the western Pacific, just at the "entrance" of the Indonesian Seas.

Some examples of the results of the South-North XBT repeat transect lines are described here. In Figure 1, the RMS values reflecting the variability of the semi-annual, annual, and inter-annual temperature variations reveal the largest longer-period variability centered at latitude 5 S in the western Pacific, just at the "entrance" of the Indonesian Seas. But for the RMS of the residual temperature

time series in Figure 2, the largest shorter-period variability is all found within the Indonesian Seas, near islands and shallow topography at latitude 6 S and just north of the Lifatamola Strait at latitude 1 S.

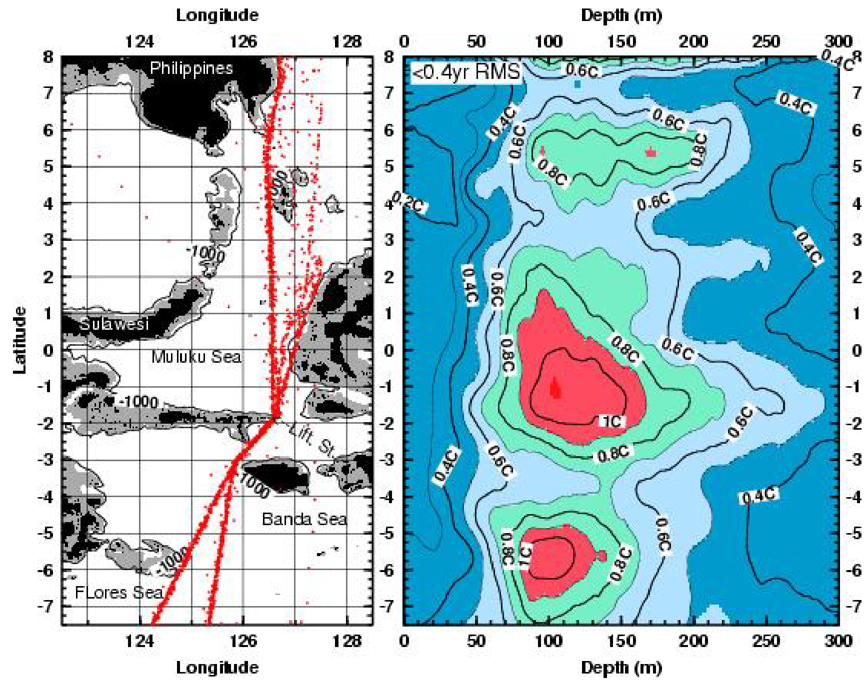

Figure 2. In the left panel the location of the XBT drops are shown, and in the right panel the Root-Mean-Square (RMS) of the residual XBT temperature data as a function of latitude and ocean depth is shown. The temperature data is the residual of the 0.4 year running Gaussian mean data. Consequently, the RMS values reflect the variability of the higher frequency temperature variations, as best can be determined with this data set. Most strikingly, the largest RMS values are not observed in the western Pacific as for the filtered XBT temperature data, but instead the largest RMS values are all found within the Indonesian Seas. Specifically, high RMS values are observed near islands and shallow topography at latitude 6 S (and at 100 meters depth) and just north of the Lifatamola Strait at latitude 1 S (and at 120 meters depth).

In Figure 3, two XBT sections that span the South-North expanse of the Banda Sea are shown. The sections are separated by 100 days, and reveal varying “wiggles” in the isotherm depths that are not obviously attributed to any general oceanographic process or current. However, when one combines the time information – it takes the ship of opportunity about 1.5 days to transect the Banda Sea – tidal information can be extracted. In this example, the 19 degree C isotherm exhibits a 50 m displacement over 0.5 day.

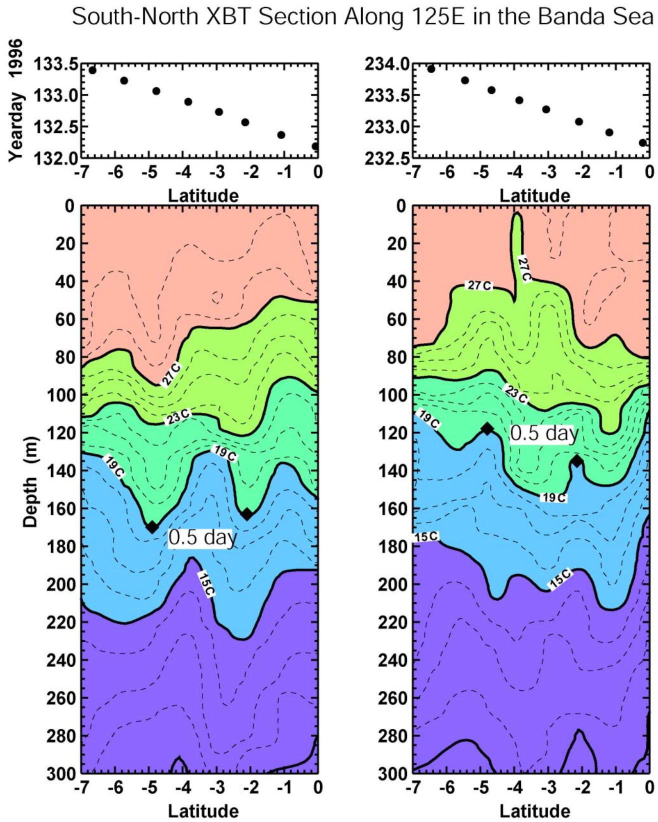

Figure 3. Two XBT temperature sections separated by 100 days are shown along longitude 125 E in the Banda Sea. The ship of opportunity takes about 1.5 days to transect the Banda Sea, and the variability in the thermocline is dominated by high frequency internal wave/tidal motions. By viewing the 19 degrees C isotherm in the sections, it can be seen that the isotherms experience on order of 50 meters semi-diurnal tidal heaving in this example.

IMPACT/APPLICATIONS

Knowing the location and magnitude of the most vigorous internal tides in the Indonesian Seas is critical to rig-based and ship-based operations due to the physical stresses upon those structures. The tidally induced turbulence and mixing will affect acoustic signals in the region as well. Estimating the vertical mixing induced by the tides will contribute to accurately modeling the ocean-atmosphere fluxes in a region that experiences dramatic ENSO repercussions.